A Portable Analyzer for Rapid and Sensitive Protein Detection by AC Electrokinetics Capacitive Sensing

Allie Skaggs and Dr. Cheng Cheng

School of Engineering and Computer Science, Elmer R. Smith College of Business and Technology

Morehead State University, Morehead, KY 40351, USA

Introduction

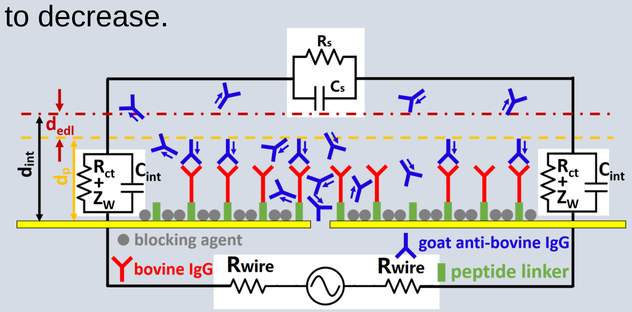
Capacitive bioparticle detection is a promising method for point-of-care diagnosis. There are a wide range of applications for such a device: diagnostics, pharmacology, and medical science. The end goal of this project is to develop a portable capacitive sensing platform for rapid and sensitive bioparticles detection. When bioparticles bind to receptors located on the surface of the electrode there would be a change in the interfacial capacitance, which indicate the presence of the bioparticle. The ADuCM355 – a precision analog microcontroller with a chemical sensor interface – is being used to perform biased electrochemical impedance spectroscopy (EIS). An AC potential is applied across the electrodes at varying frequencies, and the resulting current is measured and transferred to a master device. The ADuCM355 is controlled via the serial peripheral interface (SPI) by a master device. While multiple microcontrollers are compatible with the ADuCM355, currently a mbed lpc1768 acts as the master device receiving data to be decoded and displayed. In the future multiple sensors can be connected to a single master device and take concurrent readings for more accurate sensing.

Mechanism

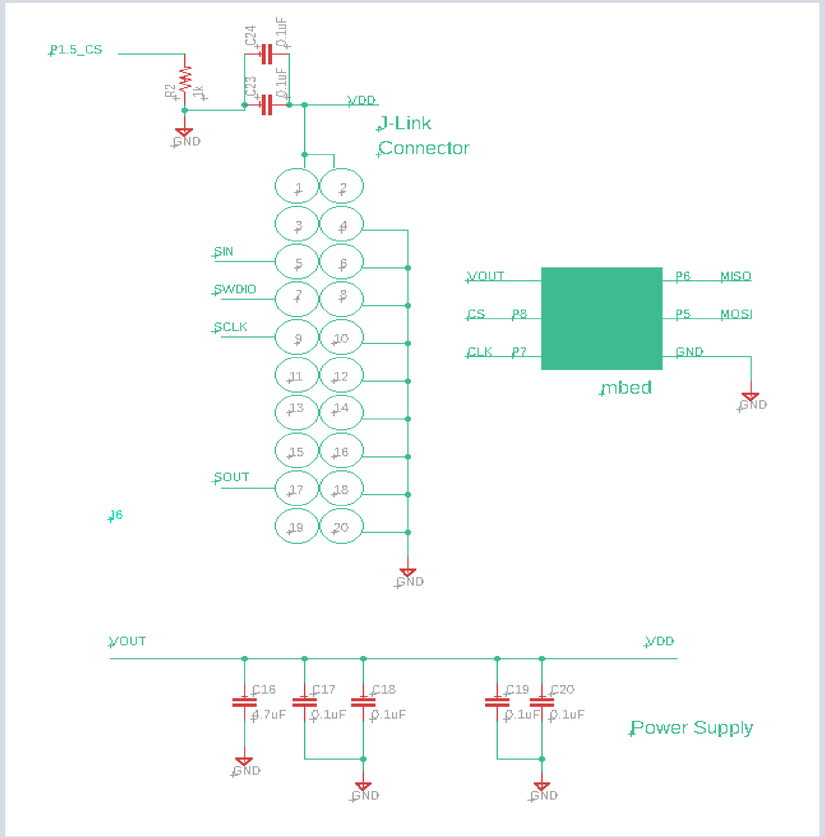
To determine the presence of proteins, the interfacial capacitance of the electrode is measured. Antibodies present on the surface of the electrode bind with antigens present in the sample. This bioparticle deposition would alter the interfacial capacitance. The relevant formulas for this is:

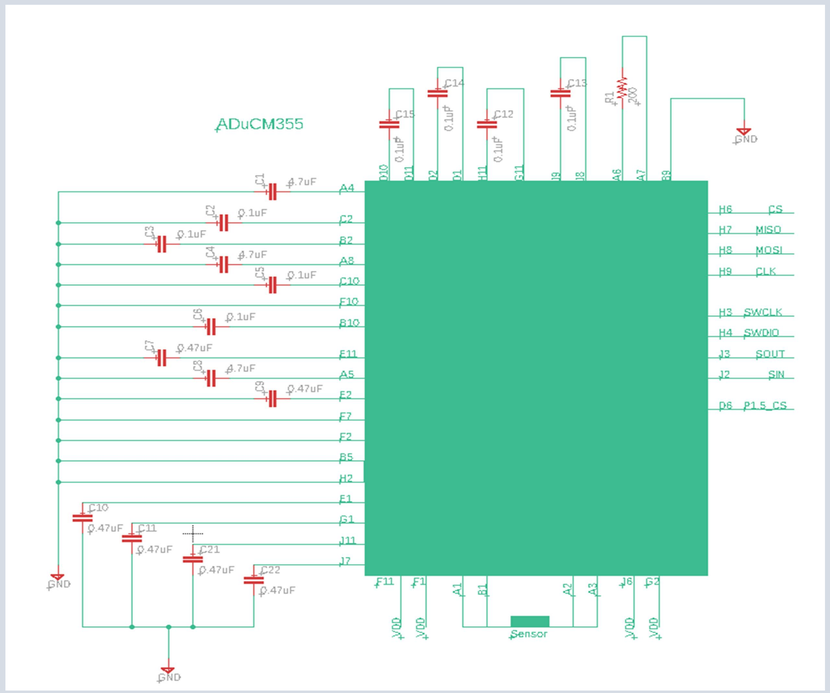
$$C_{int} = \frac{A}{4\pi k\left[\frac{1}{\varepsilon_s} d_{edl} + \frac{1}{\varepsilon_s} d_p\right]}$$

εs and εp are, respectively, the permittivity of the sample and the protein. The surface area is A, and k is Coulomb's constant. Thickness of bioparticles and electric double layer are d_p and d_{edl}. As proteins bind to the electrodes' surface the d_p increases. This causes the interfacial capacitance (C_{int}) to decrease.

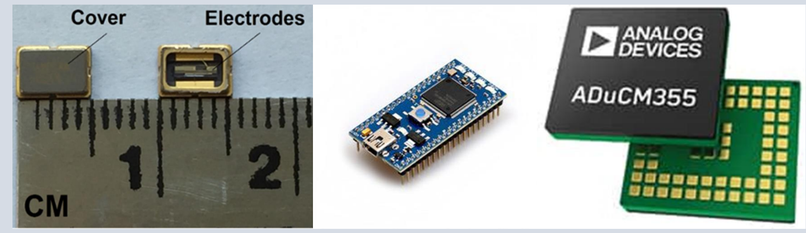


Circuit Schematic



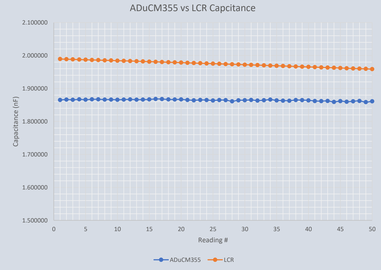


Parts



Accuracy Analysis

Below are graphs comparing results from tests run by the sensing platform and an LCR meter on the same 1xPBS sample. The tests compare measured impedance, phase, and capacitance . Tests seem to show that the device's accuracy and speed improve at higher frequencies. Based on previous tests the sensing platform when measuring in nF the average standard deviation was 0.005771.



Conclusion

The goal of this work is to create a portable, affordable, and capable of providing appropriate and adjustable AC signals using the ADuCM355 as the main microprocessor due to its chemical sensor interface with the mbed lp1768 as a master device via SPI. With the mbed lp1768 added as the master device, it will be possible in the future to add additional ADuCM355 chips, so that there can be multiple sensors performing analyses at the same time. The circuit is currently constructed on a breadboard; one of the next steps will be to make a PCB board from this design.